Weathering of granular basalt on a volcanic crater slope: an electron microprobe and synchrotron-XRD approach

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Weathering of rock primary minerals is among the first biogeochemical events that dictates the availability of major and micro elements for wider ecosystem and ultimately shapes landscape structure and its evolution [1]. This is also the focus of two multi-annual, different scale experiments initiated at Biosphere-2, University of Arizona, i.e. ‘Bio-weathering experiment’ and ‘Landscape Evolution Observatory’. Basalt, one of the major crustal renewal rocks on Earth, has been chosen as test rock in both studies.

In order to predict incipient mineralogical changes and element cycling during the experiments, and hence provide a link to natural setting, we examined basalt weathering progression at microscale from a total of 20 surface and subsurface samples collected on the external slopes of Merriam volcano at Flagstaff, N. Arizona. Samples representing both, unweathered and weathered granular basalt were subjected to electron microprobe and synchrotron-based XRD.

The analyses discriminated two major mineral transformation events. The presence of a weathering front inside grain structure (Fig. 1A) is indicative of preferential weathering and shows loss of primary ions of Ca, Na, Mg and P from both, amorphous glass matrix and embeded crystaline minerals.

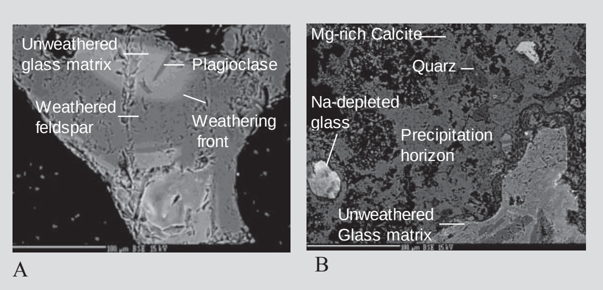

Figure 1: Microprobe results showing (A) weathering front and (B) surface grain precipitation in Flagstaff basalt

Secondly, there is evidence of low-temperature secondary phase precipitation onto primary mineral surfaces with major elements incorporating into various hydrous minerals including Mg-Al silicates, Mg and Mg-P rich calcites, Si-P calcite and quartz (Fig. 1B). The results and field assessment are consistent with large scale dissolution of glass and feldspars starting at crater top, followed by reprecipitation as Ca and Si-rich phases (often evaporites) in areas where subsurface flow at mountain base is shallow.

The effects of magma composition on the genesis of magmatic-hydrothermal ore deposits

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The composition of magmas significantly affects the likelyhood of the formation of various magmatic-hydrothermal ore deposits. Understanding the distribution of economically important metals and their key ligands (S and Cl) between the liquid, solid and volatile phases in the system is of prime importance for the prediction of the efficiency of their sequestration from evolving magmas.

We conducted experiments to investigate the solubilities and partitioning of Au, Cu, Mo, S and Cl as a function of silicate melt composition, oxygen fugacity and temperature. Gold shows the lowest affinity to dissolve in oxide matrices and its solubility is primarily controlled by reduced S-species both in magmatic volatiles and silicate melts. The efficiency of the complexation of Au by S in the latter phases is furhter increased by increasing alkali metal and chloride activities. Estimated volatile/melt partition coefficients of Au suggest that it can be extracted efficiently by magmatic volatiles from mafic to intermediate magmas in early stages of magmatic evolution.

Copper shows a much lower affinity to complex with sulfur both in the volatile phase and the silicate melt. In most magmatic volatiles, Cu-chloride complexes are predicted to be dominant, with the exception of sulfur-rich alkaline magmas. In silicate melts, Cu dissolves into the oxide matrix and its solubility is only moderately increased by the presence of S and Cl in concentrations typical of natural systems. Both increasing degree of polymerization, and decreasing temperature reduce Cu solubilities in silicate melts; however, the effect of temperature is greater. As temperature shows the opposite effect on Cu solubility in magmatic volatiles and pyrrhotite relative to the melt, it is likely that the Cu budget of evolving magmas shifts in favour of these phases. The extraction of Cu by magmatic volatiles may be prevented if the magma evolves in the sulfide stability field ($\log fO_2<$NNO+0.5) and the sulfides get entrapped in crystallizing minerals, or are otherwise left at deeper levels, preventing their later resorption due to S loss from the system during degassing. As opposed to Au, the extraction of Cu by exsolving volatiles will only be efficient from evolved magmas. Thus, input of volatiles originating from mafic magmas into the hydrothermal fluids will only promote porphyry Cu deposit formation through addition of S. Such volatiles will increase the Au/Cu ratio of the forming ore deposit in relatively reduced systems ($\log fO_2<$NNO+0.5).

Molybdenum dissolves as an oxide species, and partitions in favor of andesite melts independent of S and Cl concentrations in the volatile phase within the compositional range realistic for natural systems. It is likely that higher volatile/melt partition coefficents of Mo previously observed in felsic systems is due to the reduced solubility of Mo in polymerized melts. Therefore, efficient Mo extraction is most likely from highly evolved felsic magmas.